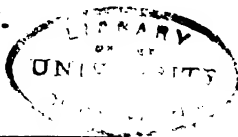


PROFESSIONAL PAPERS
OF THE
CORPS OF ROYAL ENGINEERS.

EDITED BY
CAPTAIN R. F. EDWARDS, R.E.

ROYAL ENGINEERS INSTITUTE
OCCASIONAL PAPERS.

VOL. XXIV.
1898.



ALL RIGHTS RESERVED.

Chatham :
PRINTED BY W. & J. MACKAY & CO., LTD., 176, HIGH STREET.
PUBLISHED BY THE ROYAL ENGINEERS INSTITUTE, CHATHAM.

AGENTS: W. & J. MACKAY & CO., LTD., CHATHAM.

1898.
Price, 10s. 6d. net.

CONTENTS OF VOLUME XXIV.

PAPER.	PAGE.
1. The Selection, Testing, and Employment of Cement, by A. E. Carey, Esq., M. Inst. C.E.	1
2. On the Sanitary Methods of Dealing with Epidemics, by Professor J. Lane Notter, M.A., M.D.	21
3. Hospital Construction, by Captain Sir Douglas Galton, K.C.B., late R.E.	37
4. Notes on Recent Researches on Illumination by Coal Gas, by Major G. K. Scott-Moncrieff, R.E.... ..	61
5. Tactical Employment of Field Defences, by Colonel M. H. G. Goldie, R.E.	85
6. On the Effect and Tendency of Recent Sanitary Legislation, by J. R. Clark Hall, Esq., M.A.	139
7. The Bacterial Purification of Water, by Percy Frankland, Esq., Ph.D., B.Sc., F.R.S.	159
8. Steam Engine, by Captain H. R. Sankey, late R.E.	183
9. Lessons to be Derived from Engineering Works in Great Britain, by Major G. K. Scott-Moncrieff, R.E.	225
10. Siege Railways. With Special Reference to Traffic Organization, by Lieutenant E. H. M. Leggett, R.E.	255
11. Geographical Surveying in India, by Colonel Sir T. H. Holdich, K.C.I.E., C.B., R.E.	289

PAPER XI.

GEOGRAPHICAL SURVEYING IN INDIA.

BY COLONEL SIR T. H. HOLDICH, K.C.I.E., C.B., R.E.

IN discussing the subject of "Geographical Surveying in India," it is very necessary to define at the outset what it is that we mean by India.

India is not a "country" like Britain, or France, or Germany. It is a continent as large as all Europe, and includes not only quite as many nationalities as Europe, but nationalities with far greater distinction in ethnographical characteristics and geographical surroundings than exist anywhere within the limits of Europe. There is, for instance, far more difference between the fair-skinned Pathan, or Sikh, of the north-west, and the dark-hued Dravidian people of the south, than will be found between the Welshman and Italian. The difference between the Esquimaux and the Spaniard is probably not more marked than is that between the Ghurka and the Bengali. The India of heat-ridden plains and tropical landscape, the historical India of Clive and Hastings, is rapidly changing, and our national interest in this great collection of other nationalities centres itself more and more towards the north-west—the borderland of Persia, Beluchistan, and Afghanistan—and withdraws further from the flat plains and plateaux that run to an apex at Cape Comorin. So far as geographical surveying is concerned, our interests south of the Himalayas, and east of the Indus, are at an end. Indeed one must go very far afield even on the north-west, in these days, to find any

large extent of unexplored territory, although there are many points on the border still of which it may be said that we want a closer geographical acquaintance than that which we already possess. India, for the purposes of this lecture, then, will include all those border countries with which we have been making ourselves more or less familiar during the last 15 or 20 years; thus we may add Afghanistan, Beluchistan, and Persia on the north-west; Kashmir and the Pamirs on the north; and have something perhaps to say about Burmah on the north-east. And under the term "geographical" we may accept all that class of survey which does not admit of the minute exactness in topographical detail such as is not only expected, but demanded, whenever time and opportunity are available. You will understand that geographical surveying does not vary in principle in any way from exact surveying. The difference is one of degree, and method, not of principle. The more the time at our disposal, and the better (owing to military or political conditions) our chances may be, the nearer we gravitate to the recognized standard of exact topography, and revert to the one system which dominates surveys of all classes whatsoever in India.

This system in all its stages recognizes nothing short of the most minute exactness that can be obtained by the most skilful use of the best class of instruments in the best possible hands; and it is this system which has enveloped the India of the plains south of the Himalayas long ago, and which is now partially repeated from time to time in districts whose development demands surveys on large scales, and for special objects.

I need not describe it further than to impress on you that the great skeleton of geodetic triangulation which permeates India, traversing her back from the Himalayas to Cape Comorin, and extending along her ribs in lateral lines to the coasts on either side, linked up by long series of triangles which follow the coast lines, and checked by most carefully and scientifically planned measurements at regular intervals, is the basis, the foundation, of all these long feelers which extend into Burmah, to the Pamirs, the Oxus, and the Persian borderland. These feelers may be actual unbroken series of triangles themselves, or they may be the result of a consistent series of operations more or less analogous to that of a direct triangulation; but whatever they are, they have their roots in India, and are just as certainly based on the observatory at Greenwich for their zero or starting point as are your own geographical explorations in South Wales. I wish to impress this

on you so that you should not suppose that geographical surveying, as pushed outwards into Southern Asia from the Indian border, is simple pioneering, that class of survey in which an explorer vanishes into space with instruments and equipment for the determination of his absolute position in latitude and longitude, as if his record were to be made on a trackless ocean. We never, if we can help it, lose sight of our landmarks. We fix them as we go, and they follow each other along like milestones on the great world's highway, stretching over mountains and through deserts to the farthest limits that we can reach; and each landmark is a compendium of geographical information in itself. We know not only its latitude and longitude relatively to Greenwich, but its altitude with reference to the sea, and the exact bearing or azimuth of all other visible landmarks from it. It is this which forms the distinctive feature of Indian geographical surveying, and the system is just as applicable to any other country as it is to India, or the countries round India. You will understand then that we are not dealing with exploration of that nature which the first pioneers across a great continent carry through with them, where so many other vital interests are in the field that the mere matter of a survey record becomes entirely subordinate, depending on good luck and occasional opportunity for its vitality. Such exploration is not surveying, and such records usually find final expression in a thin red line running across a more or less blank sheet of paper, with a few twisting sinuosities on either side to denote the hills. The opportunity for such exploration on the world's surface as this, is rapidly becoming so limited that it is difficult to say where future possible opportunities for the preliminary work of the pioneer may lie. On the other hand, the class of survey which we may call geographical—or first survey—is in greater and greater demand every day. Even if we have succeeded in pushing it as far as the limits of the Indian hinterland will at present permit, so far as to have secured our junction with the scientific surveys of Russia on the north-west and north, and to leave only intermediate areas for consideration, there is still much to be done even in those intermediate areas; whilst we have only to turn to Africa with its unbounded opportunities in military reconnaissance, boundary demarcations, and actual campaigning to realize that great as may have been our chances within the last 20 years in southern Asia, they are nothing to those which lie before you young R.E.'s of the present day.

Thus we may describe geographical surveying as "Topography,

based on Triangulation," just as we should describe any other form of surveying, and if triangulation in the strict sense of the term is impossible, on something as near akin to it as we can attain. This is the whole law and the gospel of geographical surveying, and you should remember that anything less does not mean surveying at all.

In the admirable school of instruction which you are so well acquainted with here you are already taught all the first principles of the science. I need tell you very little indeed about the instruments which you will use, or the manner of using them. Nothing can be more practical or to the purpose than the pamphlets which are put into your hands, giving you all the assistance you can require in the way of formula and data for projecting your survey sheets, and reducing your preliminary observations. My best advice to you is to keep them carefully, and if ever you see the opportunity of putting your instruction to practical effect, study them carefully, get the forms and the formula at your finger ends, so that there may be no hesitation and no clumsiness in the field; for when you find yourselves face to face with your work, it may well happen that even minutes are of consequence.

But the area over which there is opportunity for the practical application of your theoretical studies is inconveniently small in England. It is, moreover, impossible to find in this well nurtured country anything that is at all analagous to the wide open plains and mountain ranges of great continents, or to give even an approximate idea of what the real practical difficulties of your position may be; so, with but a very few general remarks on such preliminaries as are involved in the choice of instruments and preparation of equipment, I will confine myself to illustrations of such points as will confront you with an aspect of especial rockiness when you are once fairly in the field.

On whatever shores you first pitch your tent, wherever you first set your feet on the edge of a new domain for geographical enquiry, with its mystery of physical conformation still to be unravelled, you want four well ascertained facts as your data from which to effect your start. You must know, with reference to the particular point from which you take off (1) its latitude; (2), its longitude; (3), its altitude; (4), the true bearing or azimuth of some other point from it; and in addition to this you require a linear value, *i.e.*, an exact measurement which will form a base. Sometimes these obligatory data will be supplied to you. In India, or anywhere near India, they will certainly be supplied along with very much more important

preliminary information. You have only to apply to the survey department to get them. But if your work lies in Africa, or elsewhere, and you are dependent on Admiralty charts and other special sources of information, then be cautious in *verifying your data*. Indeed, in any case, this is a matter which cannot be too strongly impressed on you. Find out the nature of it, how it has been evolved, whether you are likely to be able to improve on it, and never under any circumstances accept a list or *précis* involving the use of figures without most careful check. You would think that all this might be unnecessary in documents emanating from high official quarters containing your instructions in precise terms. Experience has taught me otherwise. Never, under any circumstances, trust any geographical statement, especially if it involves figures, without ascertaining its authority.

Into the questions of equipment I need hardly enter at all. It is one which you will have always with you, and it varies with every phase of work and with every development of instrumental means. I will assume that you are efficiently equipped more or less on the "mobilization" scale for Indian trans-border surveys, an equipment which fits in well with what I have seen of the principles of surveying which are set before you in this school.

Given that you already possess the obligatory data to which I have already referred, and that you are landed fairly at your starting point with the long blue stretches of seemingly endless plains before you, backed, maybe, by lines of mountains which will appear like the cardboard slips of the stage, range after range crossing your horizon and full of length without breadth, your very first difficulty will be to identify and recognize those points which form your data. If there are many of them, if they consist of well defined peaks, or prominent landmarks spread in front of you, every one of them should have been previously projected in its right position in latitude and longitude, on a well mounted plane table—or, at least, on a cloth-mounted sheet of paper duly inscribed with its parallels and meridians at 5' or 10' intervals, with graduated scales of latitude and longitude drawn in it, together with a linear scale. In dealing with your plane table board, or with mounted paper, or anything else that is liable to expansion and contraction, never forget the golden rule to have all your scales on the paper so that they too may contract or expand proportionately with the board or the paper. Then make every effort to reach at least one fairly well fixed point, and from it, with the aid of your plane table,

determine the position and appearance of all the others. Lastly, consider carefully where your triangulation is to take off in extension of that which has already been completed, *i.e.*, what points will form the best ends for the new base which is to project a series perchance into the heart of a continent.

But suppose (and this after all is the most practical supposition) that you have none of these things—no initial latitude or longitude, no base, or linear value; then I have a few words to say about each of these requirements. Your value for latitude can be easily ascertained, for it can be determined on any fine night, with a six-inch theodolite, by observations to north and south stars, to within a few seconds of the truth—so far as you can tell, for there may be causes of error, to which I will refer presently, that you cannot detect. Your latitude station will form one convenient end of your base, which should be levelled and measured with all possible care. There are various methods of measurement, but none of them to my mind are better than that which involves a steel chain, and a steel tape to serve as a standard for reference. I have tried many systems, and that which has proved most satisfactory is a careful system of direct measurement with the chain in the hands of a few well-trained chainmen. Accuracy, even in chaining, is not learnt in a day, and the more practice you can get at it the better. In the course of a day a base of two miles in length may be measured some three or four times over, and the extreme differences should not exceed a few links if your chainmen are practised hands. But you will have to cut your coat according to your cloth, and your length of base will be determined by many other considerations than those of your own convenience.

Pari passu with your latitude observations at night you determine the azimuth of your base, *i.e.*, the same observation will give you both. This, with an initial longitude, furnishes all that you require to compute out the co-ordinate positions of the hill peaks and prominent objects which you have observed from either end of your base, and to project these positions on the plane table prior to commencing topography.

But the longitude? How about that? Well, my advice is that if you have absolutely no value to start upon, assume one; but treat your assumption with all respect. Do all you can to preserve it from day to day till time and opportunity enable you to apply a final constant correction throughout your work. My reason for this advice is that under most of the conditions which call for

special surveys of a geographical nature your opportunity for determining an absolute value will be but small; and when you have got the observations you will never be certain of your results. In the case of boundary demarcations, for instance, absolute determinations of longitude are frightful pitfalls. You can never tell when the telegraph will not unwind itself across your path, and at once give the lie to your astronomical deductions, upsetting your record, and scattering a constant error along the line of survey. Much better leave it alone, and accepting any approximate value which is sufficiently near the truth to introduce no appreciable error in the corrections necessary in your astronomical deductions, admit candidly that you do not know your longitude exactly. If driven to an absolute determination (and the chance of this gets daily smaller), I think that the results attained from observing the occultations of Jupiter's satellites are the most satisfactory. But remember always that the whole map system of India is still suffering from the error of the Madras observatory determinations of the longitude of India by occultations of Jupiter's satellites. It is impossible to conceive that under ordinary field exigencies you could have the opportunity for obtaining observations so well balanced and so apparently consistent as those of Madras. They were taken with all the trained experience of one of our best astronomers, and reduced with infinite care. Yet the results are wrong by two miles and a-half, an error which is an unmixed source of inconvenience, if not of difficulty, in dealing with the mapping of our European neighbours in Asia.

With the telegraph at your disposal all difficulty vanishes except the practical one of securing a free line, and as the telegraph pushes itself into every field that you are likely to enter, you will probably have far more to do with that unrivalled method of determining your position in longitude than you will with any "occultations" or "lunar distances."

I have of course necessarily omitted all reference to the details of working your instruments for the attainment of your data or your initial triangulation, feeling sure that you will learn that here better than I can tell you. You should be able to determine your position in longitude by aid of the telegraph to within a few seconds of arc (say a few hundred feet), and as nearly as you can determine your latitude. There is, however, always a hidden source of error in latitude determinations which does not affect the longitude in an equal degree. The proximity of mountain masses

or possibly of deep sea depressions, even the unceasing action of the earth's crust rising in some points relatively to the earth's centre and falling in others, produces what we call "level deflection" in various degrees, which may affect your work appreciably, and yet be indeterminate in value. For instance, the presence of the great mass of the Himalayas, north of Delna Dun, where we have one of our chief Indian observatories, pulls the level northward by force of gravitation to such an extent that no observed latitude of that place can be correct within 40 seconds of arc, or nearly a mile ! This is an extreme case, but remember that the same source of error pervades all lands of hills and plains. It is this which still leaves triangulation, or some direct system of earth measurement, a paramount necessity in such countries as have hitherto remained unmapped. Were it not for this, a telegraph wire for longitude, and a theodolite for latitude, would meet all survey requirements short of actual topography.

So when you have clear weather and unlimited time you can work out your own scheme of triangulation from your own base ; and, if you are lucky, can keep a whole staff of subordinates busy with the topography and the plane table. But it happens sometimes that the weather is not clear ; and it happens often that time is not your own ; but that you must move steadily forward by daily marches, leaving but a narrow margin of time for observations. This happened to us in our journey from Quetta to Kuhsan, near Herat, where we had to import a fixed point of departure (fixed, that is, in co-ordinate position relatively to Greenwich) as the basis of the commencement of the Russo-Afghan boundary. Our Indian triangulation carried us to the Helmund, and would have taken us yet further had not a thick haze (thick as London fog) swept down from the north, and blotted the landscape from view. We were reduced to traversing with plane table and chain for some days, till a clear view at last gave us the chance of a latitude, and an azimuth to a far distant peak lying south, which the plane table indicated to be one of the points of the Beluchistan system of triangulation. Here then we again recovered our Indian data, but not quite satisfactorily. From that point to Kuhsan we moved steadily northward, sometimes at the rate of 20 to 30 miles a day, and never lost connection again. As each day's march over those interminable Persian border flats was finished, a base was measured with the chain, and observations taken at either end, both to points already fixed behind us, and to every prominent forward peak near the

presumed line of route. The positions of these were all computed out, and the distances of the forward peaks from the base determined. As soon as the stars were visible, an extemporary observatory at one end of the base was rapidly prepared, and latitude by north and south stars, and an azimuth, were observed and computed on the spot. The base had already its approximate position marked by the topographer in the plane table sketch which he carried on from day to day. This position was now checked, and his forward points projected by distance and azimuth so as to be ready for the next day's work. Thus by linking up each day's triangulation with that of the day previous, we reached Kuhsan without a break in the line of operations; and we never left the line of route to visit a single peak (*see Plate*).

Subsequent opportunity enabled us to obtain an accurate longitude by means of the telegraph at Mashad, in N.E. Persia; and from that point direct triangulation was carried down to Kuhsan, and extended from there eastward right through the Oxus valley to Kabul. We *then* found that in the course of the upward march points had been observed which subsequently became part of the general scheme of triangulation, and we were able to reverse the process and carry the value of the Mashad longitude down by a few successive steps to the point where we had lost ourselves in mist. The telegraph value determined at Mashad only differed from that which we carried up with us by the process I have described by a few seconds in arc; and when we had crossed Afghan-Turkestan we closed on the Kabul triangulation finally with a difference that was quite inappreciable on the scale of geographical survey.

Such results as these only really prove that small errors engendered in this rough class of geographical triangulation, where no definite artificial points to be observed can be set up, and where it is merely a question of reaching the highest point you can, and observing all you can—that such errors have a tendency to counteract and to neutralize each other. There was probably a great deal more error embodied in the series than showed itself at the end of it. But such results justify all endeavours towards accuracy, and they teach the lesson of perseverance.

It may indeed happen that the measurement of small daily bases is impracticable from the nature of the country. This happened more or less in the effort to carry the triangulation of India across the Hindu Kush into the Pamir country three years ago. We were

fairly "bunkered" in the tight, narrow valleys which lead up to the little Pamir beyond the Hindu Kush. There was hardly a yard of favourable ground for a base, and huge cliffs and glaciers shut us in on either side with a solid wall of obstruction that it was hopeless to think of surmounting. But perseverance was again rewarded. The perseverance was that of Colonel Wahab, R.E., and his was the reward. He took the first opportunity that occurred of reaching the summit of an 18,000-foot peak, as we emerged into the little Pamir; and he subsequently took many others, with the result that twice he was rewarded by being able to identify on his plane table the whole array of magnificent snow pinacles that are included in the Gilgit series of Indian triangulation; and with his theodolite he obtained accurate observations not only to these peaks, which he saw overtopping the broad back of the Hindu Kush, but to many a Russian and Chinese peak as well. The daily base system was at once dropped, except for purely local purposes, and we arrived at Lake Victoria with our triangulation connected with India and the proofs of it in our hands. Much pains had been expended by the Russian staff in the determination of their own position. Not again were they to be forced into accepting our data for their topography if they could help it. They had done so previously in Turkestan. Their longitude had been carried by telegraph to Osh, within measurable distance of our camp (about 80 miles north of it in a direct line), and a fine battery of chronometers was worked in circuits till it touched our position, in order to fill in the gap. In longitude they claimed that they could not be in error with reference to Osh by more than 5 seconds of arc; and no doubt they were justified in this, for the Russian chronometric work is of first-class order. They assumed the value of Osh to be definitely fixed with reference to Greenwich. We could claim something even a little better, granted that the telegraphic longitude of India could be assumed as absolutely correct. As regards latitude, it happened that much depended on the latitude of Lake Victoria. It was a factor in the international agreement; and it was necessary to be very exact about it. So there was unusual interest attached to the comparison of our respective values, both in latitude and longitude, of pillar No. 1 at the eastern end of the lake. In longitude we found to our surprise that we had nothing to discuss. To the very last second of arc our results (Russian and English) agreed; but in latitude they claimed a position some 10 seconds to the north of ours, as the result of their astronomical determinations.

But we had not only astronomical determinations of our own to depend on, we had also the very remarkable result of a direct connection by triangulation with India—and these results tallied with our “astro” determination to a second. Thus there was really no further room for argument, and we maintained our position.

Before I drop the subject of triangulation let me remind you that *altitudes* are a large feature of it, and that the relative relief or altitude of the plains and hills of the geographical area before you is a very important part of its configuration. But whilst you should never neglect to take observations for altitude to all high and prominent points, you should remember that the practical workman wants to know the heights of the plains and plateaux quite as much as the heights of the mountains, and that the latter are only really important as points for reference to your topographers in the plains. Whilst on this subject let me advise you to depend as little on barometric determinations of all sorts as you possibly can, and adopt the practice of taking altitudes with a small angle-measuring instrument (such as the clinometer) which can be usefully added to the topographical equipment. Whilst pursuing your work of triangulation with the theodolite be careful to secure reciprocal or complimentary observations for altitude as often as you can. It is only where you possess the double observation (*i.e.*, from A to B and from B to A) that you can determine a general value for refraction which will be applicable to your other observations which are not reciprocal. This is an important point, for although the tables included in your admirable Survey School notes give a co-efficient of refraction which equals 0.07, it is not at all unusual for the atmospheric conditions (especially in high altitudes) to be such as to cause a very considerable modification of this average value, and to necessitate recasting the tables. I have said nothing so far about your initial altitude, which, with the latitude and longitude of your initial point, is a necessary datum for the commencement of your survey. This, if it must be an absolute determination, is always a matter of difficulty, requiring a long series of careful observations spread over several weeks, together with a contemporary record of barometric readings, either at the sea coast or some point of which the altitude is already well ascertained. You are under these circumstances reduced to dependence on barometric results, and the instrument which I should recommend you to make use of is George's standard mercurial barometer, which packs more readily, and is less liable to damage, than most. It requires a little

careful manipulation to expel the air completely from the tube, and it is sometimes a little difficult to read ; but it is on the whole the most satisfactory instrument with which I am acquainted. It certainly gave us excellent results in the Pamirs, where, as I have said, we were not dependent on the value obtained from it, as we had a direct connection by triangulation with India. In Turkestan during the progress of the Russo-Afghan boundary demarcation the results were not so satisfactory, and we had to await the comparison with Russian daily records on the Caspian Sea before we could dispose of an error which, if I remember right, amounted to nearly 500 feet.

There is not much more that I need add on the subject of triangulation. Remember General Woodthorpe's golden rule "get as high as you can ;" "observe all that you can ;" and even if you do not quite see your way to the extension of a well-balanced series of triangles across the country which lies before you to map for the first time, do not despair, or abandon the use of your theodolite. Remember that a latitude combined with an azimuth to any far distant point (the further the better) either north or south of you gives you your longitude with reference to that point with a precision equal at least to that with which you can ascertain your latitude ; and that you could, if necessary, carry your longitude down with you from Cairo to the Cape of Good Hope by this method with facility and exactness.

Now for a word or two about topography, and here I feel that I am perhaps treading on delicate ground. It is not at all unusual for young officers to count themselves as finished practical topographers when they have mastered the use of the plane table. Thank heaven ! in these days every officer knows more or less of the use of that very simple instrument. It is so very simple, and the problems involved in its use are of such an elementary character, that I need not refer to them in detail. I can safely leave that to your instructors. For geographical purposes the plane table has long ago superseded all other forms of instrument, or combination of instruments, that ensure accurate topographical delineation ; and the only difference that now exists between our fashion of using it on the Indian border and the practice of America or Russia is that we do not claim for it that, under any circumstances, it can supersede the theodolite. Russians and Americans do claim this. Russian artists save themselves much preliminary work in mountain climbing, and subsequent labour in computing theodolite observations, by the

simple process of what they call graphic triangulation — that is to say, that by adding slow motion screws to the azimuthal movement of the plane table, and by a few extra refinements to the “alidade” or plane table ruler (such as a telescope), they turn the plane table into an alt-azimuth instrument of a very inferior class, and carry out their triangulation with it alone. I have the greatest admiration and respect for Russian surveyors. Their geodetic and strictly scientific work is of a quality which surpasses our English triangulation, and is nearly, if not quite, on a level with that of India; but their graphic triangulation with the plane table is a failure. They are occasionally hopelessly in error before they have extended 100 miles from the original base. But all general rules have their exceptions, and there are circumstances under which we are obliged to use the plane table as a triangulating instrument. What I wish to impress on you at starting is that a man who knows how to use his plane table is not necessarily a good plane tabler any more than a man who knows how to use a gun is a good shot. The one requires as much practice with trained eye and trained hand as does the other. So generally has this come to be recognized nowadays that we employ a special staff of workmen in India (and you will find them in Africa also) to work as topographers and explorers; men who have spent years in the topographical branch of the survey department, working under all sorts and conditions of climate, in every variety of country, from the wide stony plateaux of Beluchistan to the dense forest-clad tropical hills of Burmah. They are selected men to begin with, often drawn from the ranks of the native army, and many of them have passed what is called the Rurki class with distinction. Thus we get the best of good material to work upon, and words would either fail me, or appear too extravagant, were I to record my opinion of what these native surveyors have done in clearing up the waste places of Asiatic geography. Some of them have a perfect genius for rapid topographical delineation of ground. Most travellers in the Asiatic wilderness draw on our resources for assistance of this description, and there is not one of them who has written of his travels and experiences who has not been enthusiastic when he refers to the determined, patient, untiring devotion to their work evinced by these men—Welby, of the 18th Hussars, who lately crossed Tibet from end to end, and has written so well of his adventures; Bower, of the 17th B.L., who preceded Welby on a more northerly track; Frank Younghusband, who struck into the “Heart of a Continent;”

Theodore Bent, who, ere he died, cleared away the mists from the mediæval geography of southern Arabia and Abyssinia ; Sykes, of the Queen's Bays, who has ransacked Persia from end to end—all these men have made use of them. Littledale alone did not rely on any assistance ; but there are very few men capable of uniting patient persistence in surveying with the untiring energy of the sportsman as Littledale does. His work is most admirable, but it is not saying too much to suggest that it would have been better had he made use of trained assistance.

But whilst I wish to impress on your minds that even the excellent practical instruction which you get here cannot turn you into finished workmen without the experience of all those countless varieties of stress and difficulty which are only to be met with in larger fields, I can hardly place too high a value on the advantages of this preliminary training. It is everything to know for a certainty that an officer (inexperienced as he may be) knows what he is about when he is associated in the field with surveyors ; that he will begin his work at the right end, and continue on sound methods. For illustration, I can quote the late campaigning in Tirah, which, added to the opportunities afforded by expeditions to the Tochi valley, to the Mohmand country, to Swat and to Buner, so severely taxed the resources of the survey department in trained officers, that I found myself almost single-handed with two divisions of the Tirah F.F. moving over a large extent of new ground to provide for. Geographical surveying, as you are aware, is not always carried out with the advantages of a political mission to back it, or the opportunities afforded by peaceful occupation of the country. Our frontier military expeditions have done more than political missions to open up new military surveys of the borderland, and this particular occasion was one of importance. Not only had we never seen the Afridi country, but the chances were great that we should not see it again, whilst it is not too much to say that had we been able to obtain really sound geographical information beforehand the whole plan of the campaign might have been altered. In the course of this combination of military topography with general geographical mapping it happens usually that the information obtained from day to day is required on the spot. You know enough about plane tabling to be aware that a general outline of the main features of any hill country can often be obtained from a distance ; passes can be located, altitudes of them fixed, and prominent towns and villages with their connecting roads mapped

in, long before they are reached. Thus the military mapping connected with these expeditions is of great practical value at the time, both as illustrative of the physical conditions of the country in front, as well as descriptive of that already passed over. It happened in this case that no triangulation was possible. The support of a full division would hardly have been sufficient to safeguard a survey party to any sufficiently commanding point to enable the theodolite to be used effectively, and no division was available for such purposes. But there were a certain number of prominent landmarks already fixed from long distances, the outriggers of previous expeditions north and south and east of Afridi land, that, combined with a few well-known frontier peaks nearer the Indian border, justified our plane tabling on the normal military scale of one inch=one mile. There was no difficulty about the native plane tablers. I had my reserve of them at the Quetta headquarters of the survey—good men and true, drawn from the ranks chiefly, and well tried in many fields—but officers? Where was I to get the indispensable leaders for the divisional parties who were to tackle the generals about escorts, watch for the opportunities afforded by foraging parties or scouts; decide what points could be reached; keep the plane tabler from interference whilst he applied himself solely to his own work; decide when he was to clear out of danger; take altitudes for him, and relieve him of all the inevitable wrangling with guides and interpreters; in fact, do everything except the actual topography, and keep a keen eye on that too? Well, now, any of you young officers who have had your training here, who might be in hard training for hill climbing (this is very necessary), good linguists, and the happy possessors of persuasive manners with your superiors, could do this thing. I found two such officers, and one of them was Lieut. Leslie, R.E., who (well supported by a native plane tabler who possessed iron nerve and the constitution of an athlete, combined with that eye for country that it seems to me only hill men possess, and excellent artistic skill) soon found himself an authority for the movement of troops, and won the special recognition of the Commander-in-Chief. He is now Major Leslie, I am glad to say, and his views on geographical surveying have doubtless expanded. He had nothing but his Chatham training to support him at starting. I give you a trace* of the work done with the Tirah force (I regret that it is such a rough copy, but

* Not reproduced.

there was no time to prepare a better one), and you may note that the greater part of it was done under fire, and that during the process Leslie's plane table was twice hit. There were of course two or three other parties in the field besides his, but they had not his opportunities.

I should like to add a few words upon field reproduction of mapping. Reproductions are almost essential nowadays to the general's report on a campaign, and special plans prepared during the actual progress of an engagement on scales somewhat larger than the normal geographical scale—*i.e.*, three or six inches per mile, are very much appreciated for the purpose of illustrating the movement of troops during an action. Our system in India has been to use a small printing frame and sensitized paper (usually ferrotype), and to reproduce the plan of action as soon as the drawing ink on the tracing cloth is dry by the process of sun printing from a tracing which acts as a negative. This reproduces in white outline on a dark blue ground, and is to my mind as clear a form of reproduction and as satisfactory an illustration as can be desired. It can be turned into blue printing on a white ground by preparing a negative from the trace with some form of photographic paper, and using this instead of the original trace to print from. Another process (called the ferro-gallic) for producing black outline on white ground is much in vogue in the Ceylon survey, and gives most excellent results; but it requires the use of a specially prepared patent paper which might not stand exposure, or retain its qualities if not fresh. All these processes require the use of a tent for the sake of darkness during manipulation. This is a disadvantage, for in these days even a small 80-lb. Kabul tent is looked on with suspicion as savouring of luxury in campaigning. It is a subject which requires your best attention here at headquarters, for I am convinced that we have not yet solved the problem of field map reproduction satisfactorily. At present we want a whole day to reproduce a dozen copies—and this is too much for modern war exigencies.

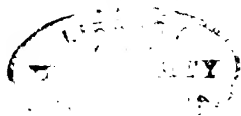
Now to sum up those points to which I desire your special attention.

- (1). Verify your original data. Be sure you have all you can get, and that you are not building up an elaborate construction on a foundation of sand. I assure you there have been some serious difficulties lately raised in the field of boundary demarcation by omitting this precaution.

(2). When making your start, direct all your efforts towards initial accuracy. Remember that one observed angle is worth 50 deductions, and stick to the very simplest form of triangulation that is possible. The simplest means to attain the simplest form is to get as high as you can, and to observe all you can.

(3). Get your latitudes with the utmost care, and *frequently*; also introduce fresh azimuthal values from astronomical deductions *often*; and *occasionally* check your linear values by a fresh base.

(4). Don't involve yourself in the determination of an absolute longitude if you can help it. Endeavour rather to tie on to any existing longitude that is available, till the good time comes when you can arrive at a satisfactory determination by telegraph. Remember that the absolute longitude value matters little in comparison with the differential value. It does not matter what the longitude of Africa may be so long as we are all agreed to use the same value. Supposing, for instance, that your work ties on that of some neighbouring power in Africa, and that you meet on a meridian line accepted as the boundary by treaty. Meridians form the worst possible boundary definition, but that does not prevent their employment by high officials who do not know how longitudes are fixed; and you may find yourself facing this difficulty. In such a case your absolute determination may easily place that line two miles too far west, and your international colleague may place it as much to the east. Where, then, is your boundary? Your absolute determination is no better than his, probably, and even if you come to a mutual decision, it will finally never reconcile itself to surrounding geography as soon as that geography is based on a sound determination. If, on the other hand, you can start with a sound determination, never let it go. Carry it by triangulation to the end of your work, and carefully preserve your computations as you go. The instant that discussion arises, be able to appeal to them as the groundwork of your faith in your position. If your computations are sound, they will never be seriously discussed by a scientific adversary, who can only make his bow and adopt your conclusions.



RY COMMISSION.

IN EXECUTED —
MARCH . —

ngitude of Kushan.
pleted in 19 days.

